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**Kushta et al.**

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(54) **BROADBAND PATCH ANTENNA**

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(73) Assignee: **NEC CORPORATION**, Tokyo (JP)

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***H01Q 9/04*** (2006.01)
***H01Q 21/06*** (2006.01)

(52) **U.S. Cl.**
CPC ........... ***H01Q 9/0414*** (2013.01); ***H01Q 9/0442*** (2013.01); ***H01Q 9/0457*** (2013.01); ***H01Q 21/065*** (2013.01)

(58) **Field of Classification Search**
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USPC .......................................... 343/700 MS, 893
See application file for complete search history.

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*Primary Examiner* — Hoanganh Le

(57) **ABSTRACT**

An antenna of the present invention includes: a first conductive patch having a rectangular shape with corrugations on two opposing sides; and a second conductive patch below said first conductive patch and connected to a feeding point.

**10 Claims, 16 Drawing Sheets**

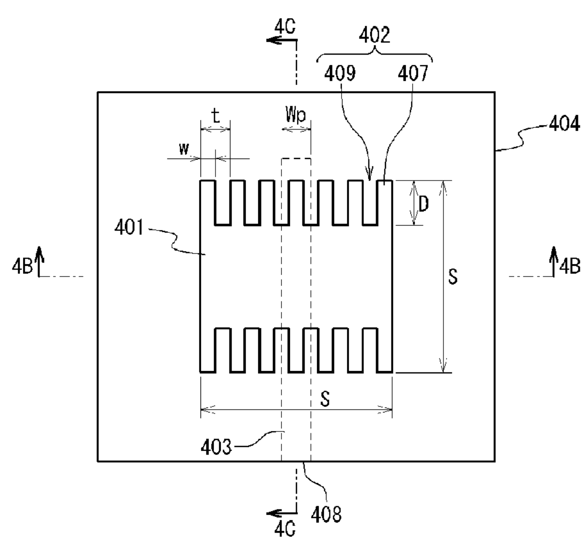

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Fig. 1

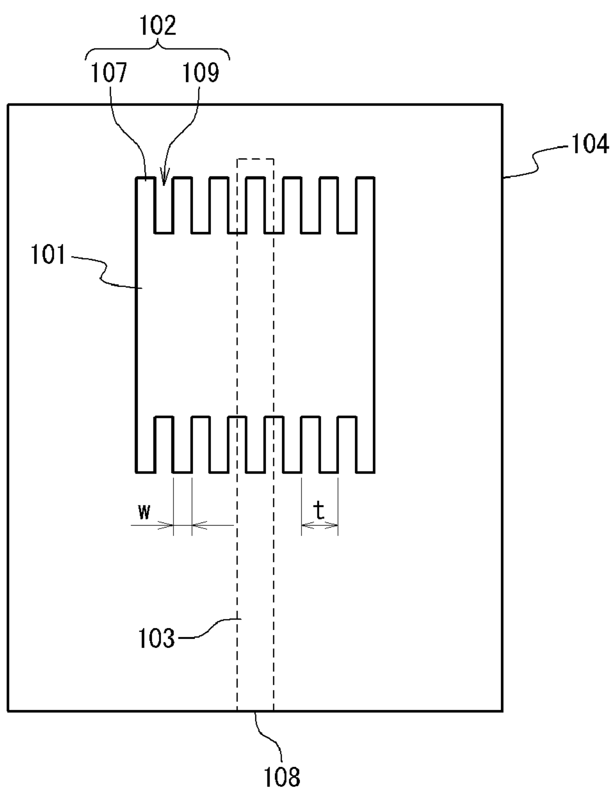


Fig. 2

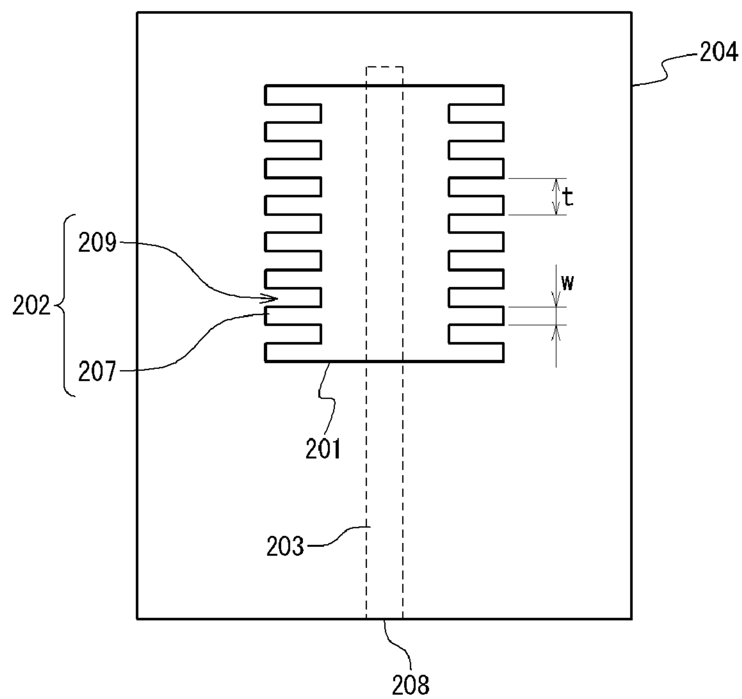


Fig. 3

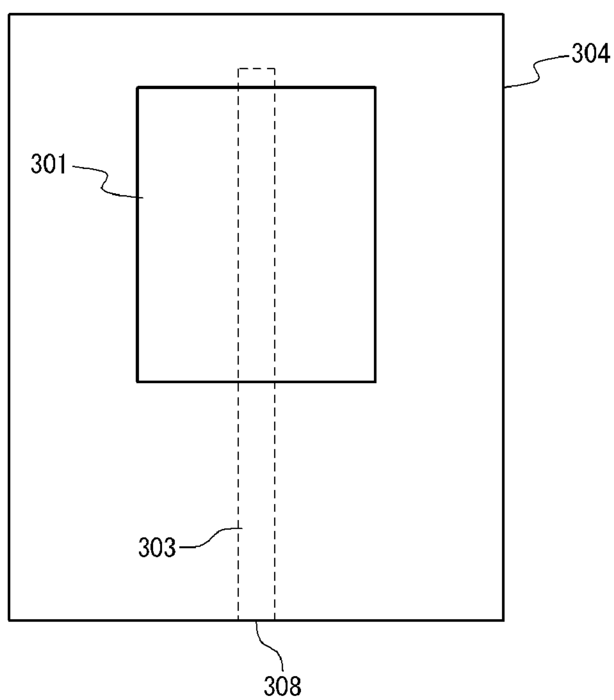


Fig. 4A

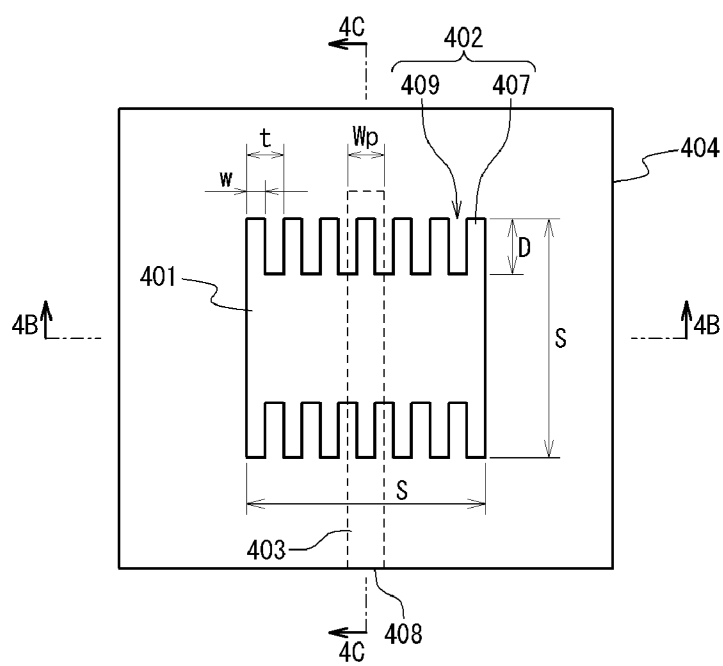


Fig. 4B

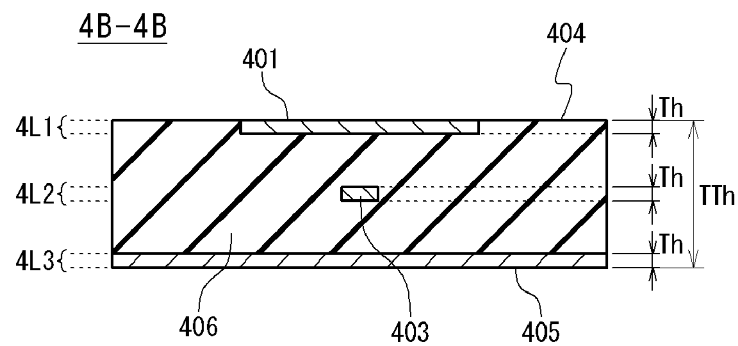
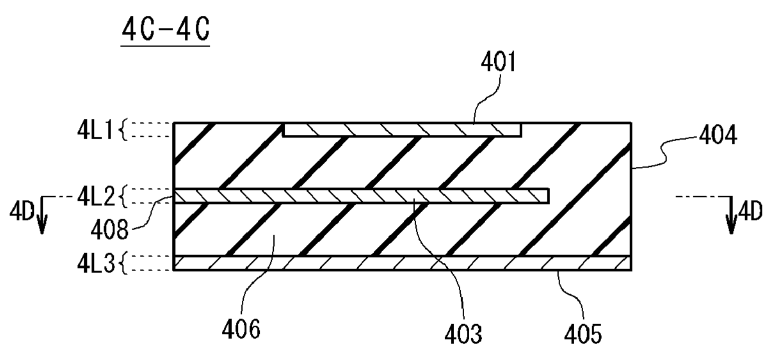

4B-4B
401
404
4L1
4L2
4L3
Th
Th
Th
TTh
406
403
405

Fig. 4C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404
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4L3
4D
4D
408
406
403
405

Fig. 4D

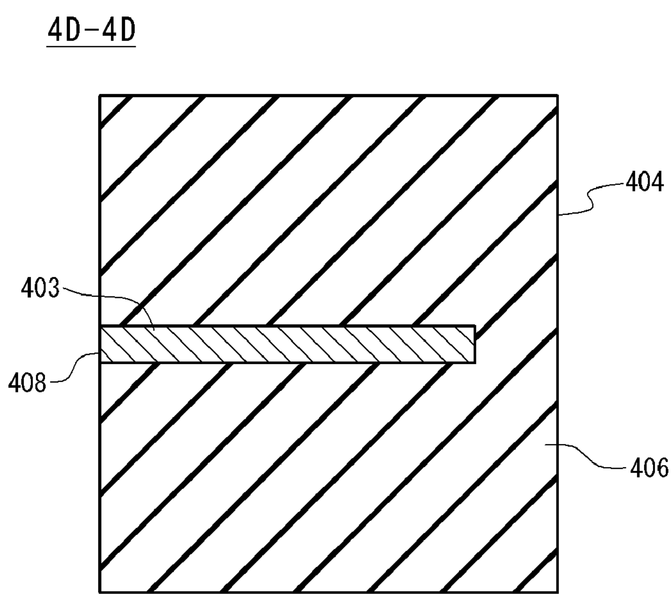


Fig. 5A

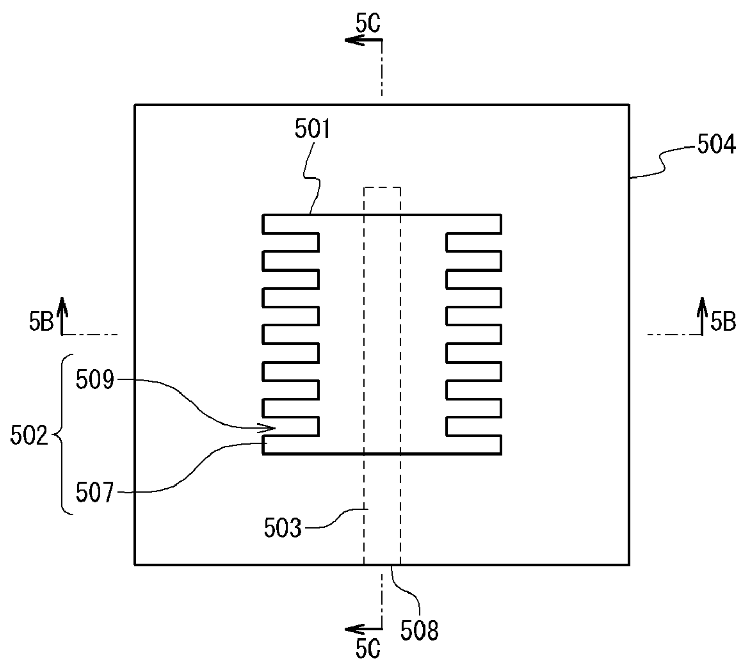
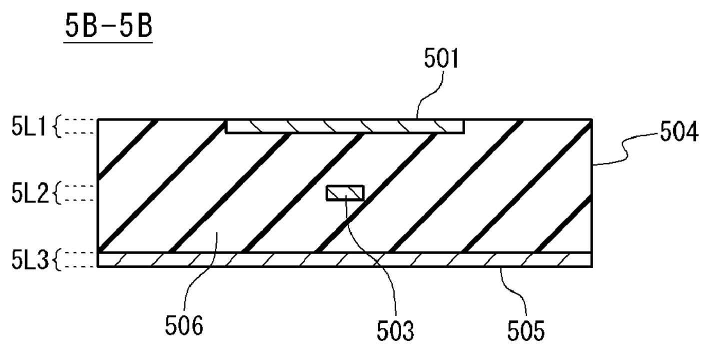


Fig. 5B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5L1
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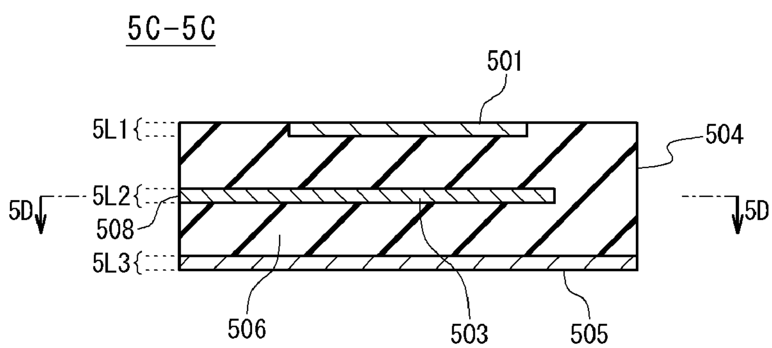
5L2
5L3
506
503
505

Fig. 5C


5C-5C
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5L1
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5D
5L2
5D
508
5L3
506
503
505

Fig. 5D

5D-5D

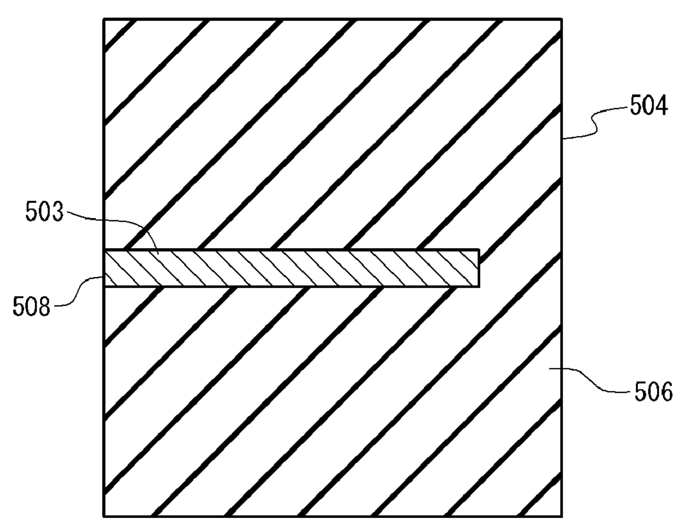
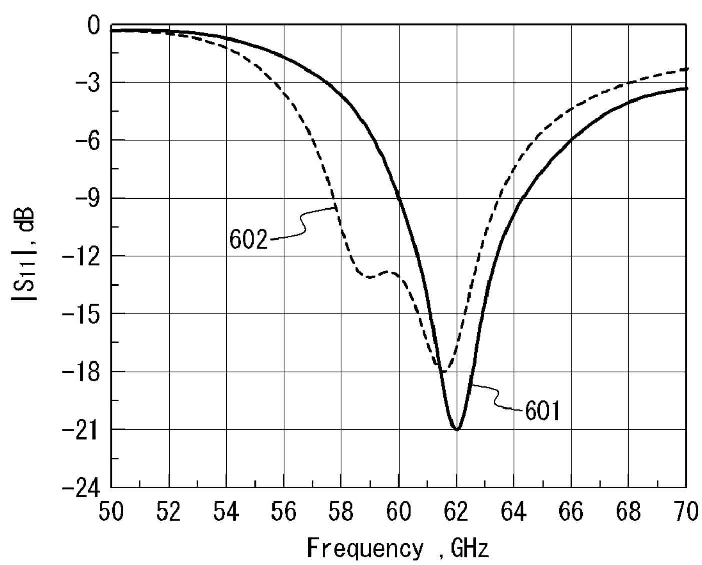


Fig. 6



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|S11|, dB
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70
Frequency , GHz
602
601

Fig. 7

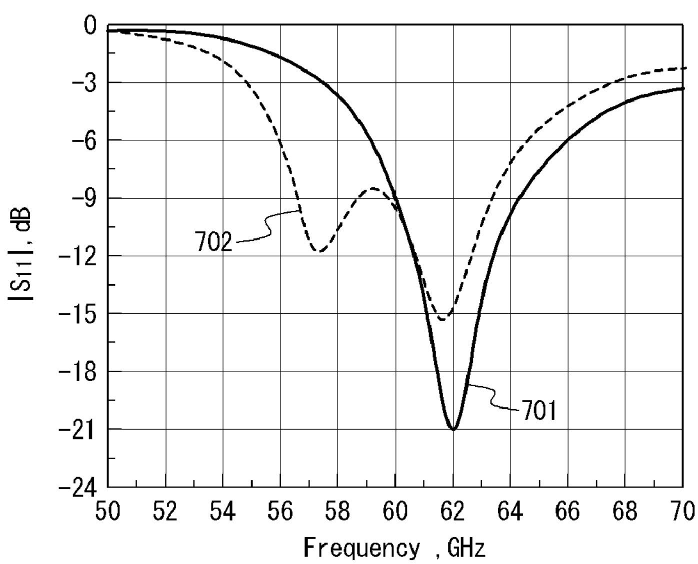
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Fig. 8

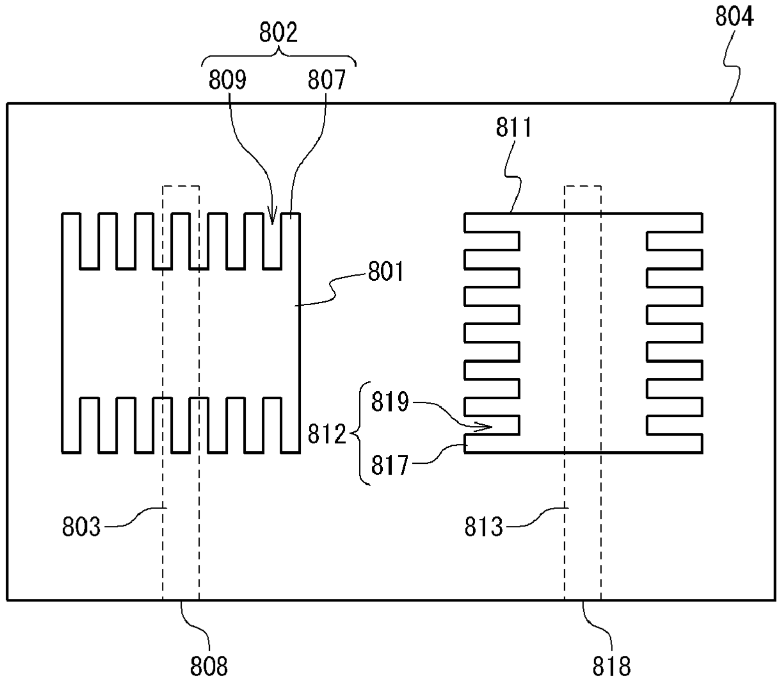

Fig. 9

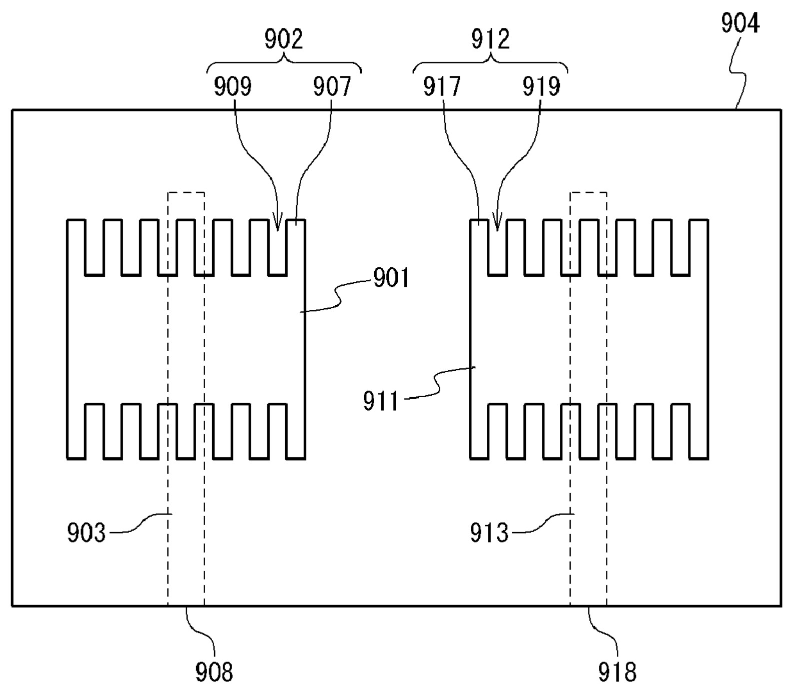

Fig. 10

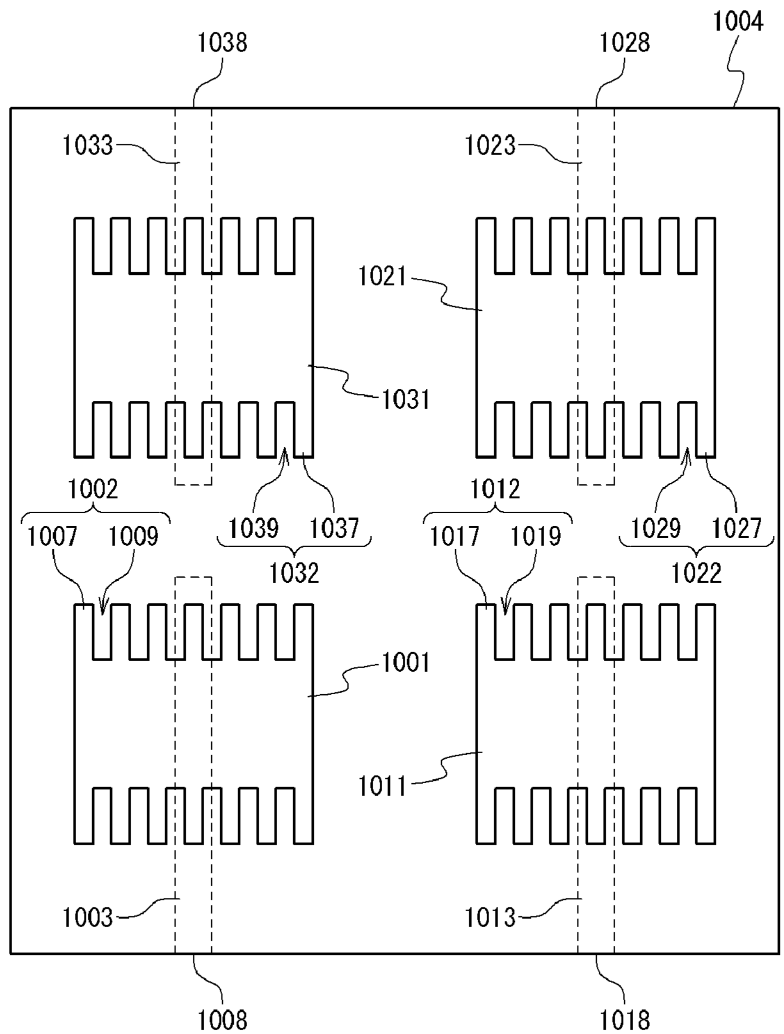
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Fig. 11

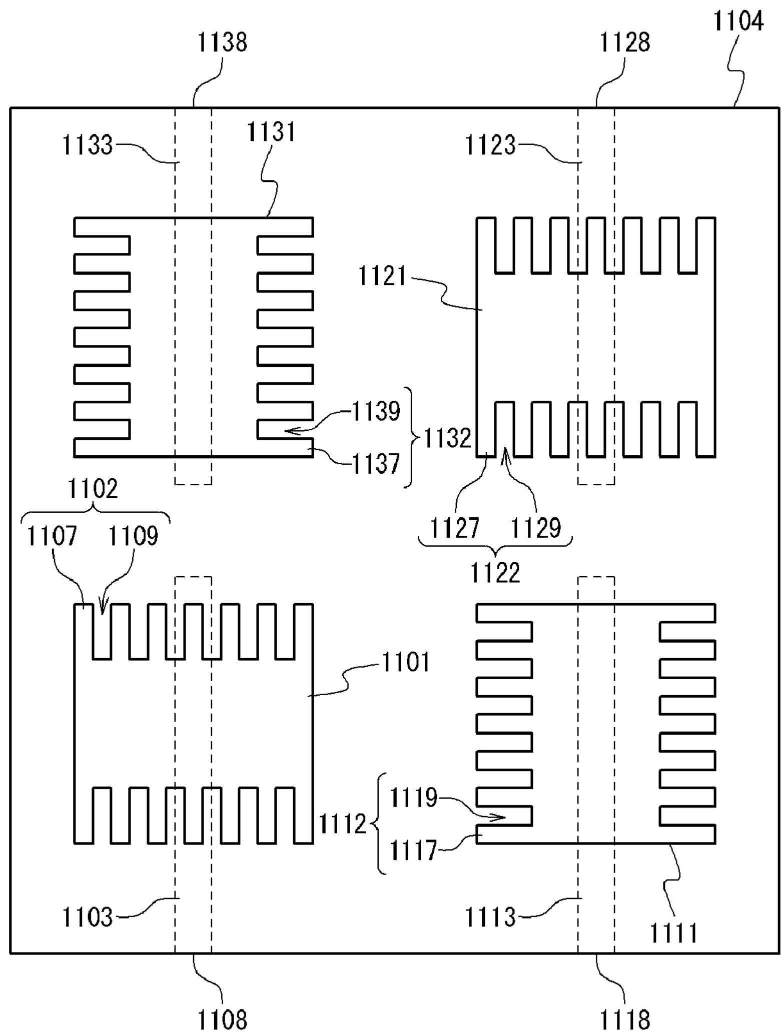
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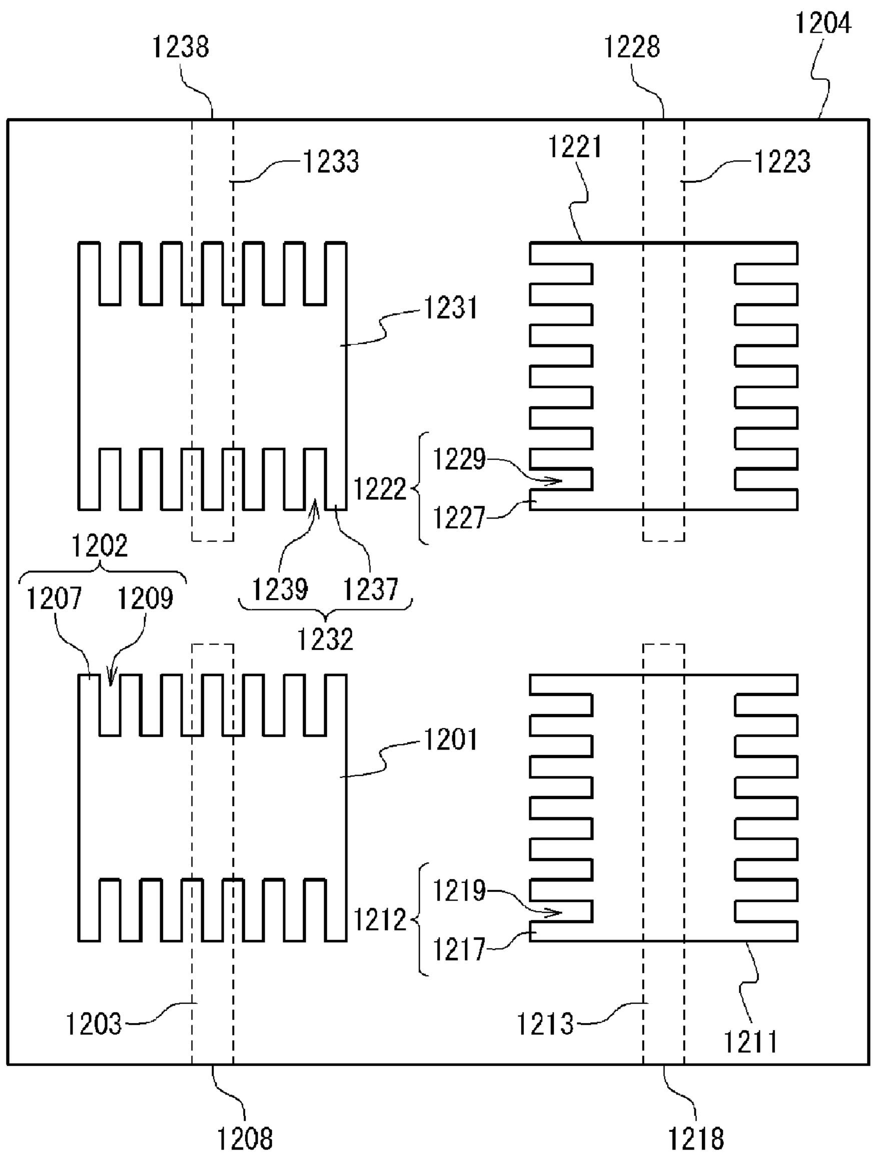
Fig. 12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# BROADBAND PATCH ANTENNA

This application is a National Stage Entry of PCT/JP2011/002693 filed on May 16, 2011, the contents of all of which are incorporated herein by reference, in their entirety.

## TECHNICAL FIELD

The present invention relates to broadband antennas for microwave and millimeter wave.

## BACKGROUND ART

Antennas are key components in wireless communication systems. To make such systems competitive in the market, miniaturized and cost-effective antennas are necessary. Moreover, bandwidth for the antennas has to be wider to provide a high-speed data transmission by means of the systems. To achieve these targets, patch antennas based on multilayer substrate technologies are one of possible solutions.

In US2010/0194643A1, a wideband patch antenna is described. In this patch antenna a helix-shaped probe is used to provide enlargement of the width of the frequency band.

In U.S. Pat. No. 7,432,862, a broadband patch antenna is presented. The broadband range in this invention is obtained by forming the patch as a cross.

However, cost and electrical performance are main issues for these patch antennas and should be improved.

Thus, it is important to obtain patch antennas which can be cost-effective, compact and can be used in a wide frequency band.

## CITATION LIST

### Patent Literature


[PTL 1]
US2010/0194643A1
[PTL 2]
U.S. Pat. No. 7,432,862


## SUMMARY OF INVENTION

It is an object of the present invention to form a patch antenna using a multilayer substrate technology which can provide a broadband operation of a communication system. Here, such broadband operation is obtained by forming a patch in the multilayer substrate with corrugations at its edges or its sides.

It is another object of this invention to form corrugations at the patch edges or the patch sides in which ridges are in parallel to the longer side of the second rectangular patch disposed under the first conductive patch.

It is another object of this invention to form corrugations at the patch edges or the patch sides in which ridges are perpendicular to the longer side of the second rectangular patch disposed under the first conductive patch.

An antenna of the present invention includes: a first conductive patch having a rectangular shape with corrugations on two opposing sides; a second conductive patch below said first conductive patch and connected to a feeding point; and an isolating material between said first and said second conductive patches.

## BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a top view of an antenna in which the first patch has corrugations with ridges directed in parallel to the longer side of the second patch.



FIG. **2** is a top view of an antenna in which the first patch has corrugations with ridges directed perpendicularly to the longer side of the second patch.

FIG. **3** is a top view of relating art antenna.

FIG. **4**A is a top view of an antenna disposed in a multilayer substrate in which the first patch has corrugations with ridges directed in parallel to the longer side of the second patch.

FIG. **4**B is a vertical cross-sectional view of the antenna shown in FIG. **4**A on the **4**B section.

FIG. **4**C is a vertical cross-sectional view of the antenna shown in FIG. **4**A on the **4**C section.

FIG. **4**D is a horizontal cross-sectional view of the antenna shown in FIGS. **4**B and **4**C on the **4**D section.

FIG. **5**A is a top view of an antenna disposed in a multilayer substrate in which the first patch has corrugations with ridges directed perpendicularly to the longer side of the second patch.

FIG. **5**B is a vertical cross-sectional view of the antenna shown in FIG. **5**A on the **5**B section.

FIG. **5**C is a vertical cross-sectional view of the antenna shown in FIG. **5**A on the **5**C section.

FIG. **5**D is a horizontal cross-sectional view of the antenna shown in FIGS. **5**B and **5**C on the **5**D section.

FIG. **6** is a group of graphs showing an effect of the corrugations at the patch edges on the bandwidth shown by means of simulated return losses.

FIG. **7** is a group of graphs showing an effect of the corrugations at the patch edges on the bandwidth shown by means of simulated return losses.

FIG. **8** is a top view of an antenna comprising two elements in which the first element has the first patch with corrugations directed in parallel to the longer side of the second patch, and the second element has the first patch with corrugations oriented perpendicularly to the longer side of the second patch.

FIG. **9** is a top view of an antenna comprising two elements in which the first element has the first patch with corrugations directed in parallel to the longer side of the second patch, and the second element has the first patch with corrugations oriented also in parallel to the longer side of the second patch.

FIG. **10** is a top view of an antenna array comprising four elements in which the first patches have corrugations with ridges oriented in parallel to the longer side of the second patches.

FIG. **11** is a top view of an antenna array comprising four elements in which the first patches have corrugations with ridges oriented both in parallel and perpendicularly to the longer side of the second patches.

FIG. **12** is a top view of an antenna array comprising four elements in which the first patches have corrugations with ridges oriented both in parallel and perpendicularly to the longer side of the second patches.

## DESCRIPTION OF EMBODIMENTS

Hereinafter, several types of broadband patch antennas disposed in multi layer substrates according to the present invention will be described in details with reference to attached drawings. But, it would be well understood that this description should not be viewed as narrowing the appended claims.

### First Embodiment

In FIG. **1**, an exemplary embodiment of a broadband patch antenna is shown. In this embodiment, the antenna is formed in a multilayer substrate **104**. The multilayer substrate **104** includes a first conductive layer and a second conductive layer. The first conductive layer includes a first conductive patch **101**. The second conductive layer includes a second conductive patch **103**. The first conductive patch **101** has a rectangular shape with corrugations **102** on two opposing sides. The corrugations **102** include rectangular ridges **107** and rectangular grooves **109**. The second conductive patch **103** has a rectangular shape.

The multilayer substrate **104** can further include an isolating material and a third conductive layer, both of which are not shown in FIG. **1**. In this case, the third conductive layer can include a ground plane, which is not shown in FIG. **1**.

The second conductive layer is disposed below the first conductive layer. Consequently, the second conductive patch **103** is disposed below the first conductive patch **101**. One end of the second conductive patch **103** is connected to a feeding point **108**.

The isolating material can be disposed between the first and the second patches **101** and **103**. The ground plane can be below the first and the second patches **101** and **103**, and in this case the isolating material can also be disposed between the second patch **103** and the ground plane.

The corrugations **102** are constructed to enlarge the bandwidth of the antenna.

It should be noted that the direction of the ridges **107** in the corrugation **102** with respect to the orientation of the second conductive patch **103** is a distinguishing and important point of the invention. In the characteristic embodiment shown in FIG. **1**, the ridges **107** of the corrugations **102** are directed in parallel to the longer side of the second conductive patch **103**. In this case, the electrical field radiated from the second conductive patch **103** is parallel to the ridges **107** of the corrugations **102**. As a result, the electromagnetic properties of the corrugations **102** can be approximately described by a one-dimensional inductive grid, for which the impedance, Z(g,ind), can be roughly defined as following:

$$Z(g,\mathrm{ind})=j\cdot Zs(t/\lambda)\cdot\ln(\mathrm{cosec}(\pi\cdot w/2t)) \tag{1}$$

where j is square root of −1, Zs is the characteristic impedance of the isolating material between the first and the second conductive patches **101** and **103**, t is the pitch of the corrugations **102**, and w is the width of one ridge **107**, as shown in FIG. **1**.

Thus, the corrugations **102** of the first patch **101**, in which ridges **107** are oriented in parallel to the wider side of the second and feeding patch **103**, provide an impedance-transforming circuit, which can be used for widening the bandwidth of the patch antenna.

## Second Embodiment

In FIG. **2**, another exemplary embodiment of the broadband patch antenna is presented. In this embodiment, the antenna is formed in a multilayer substrate **204**. The multilayer substrate **204** includes a first conductive layer and a second conductive layer. The first conductive layer includes a first conductive patch **201**. The second conductive layer includes a second conductive patch **203**. The first conductive patch **201** has a rectangular shape with corrugations **202** on two opposing sides. The corrugations **202** include rectangular ridges **207** and rectangular grooves **209**. The second conductive patch **203** has a rectangular shape.

The multilayer substrate **204** can further include an isolating material and a third conductive layer, both of which are not shown in FIG. **2**. In this case, the third conductive layer can include a ground plane, which is not shown in FIG. **2**.

The second conductive layer is disposed below the first conductive layer. Consequently, the second conductive patch **203** is disposed below the first conductive patch **201**. One end of the second conductive patch **203** is connected to a feeding point **208**.

The isolating material can be disposed between the first and the second patches **201** and **203**. The ground plane can be below the first and the second patches **201** and **203**, and in this case the isolating material can also be disposed between the second patch **203** and the ground plane.

The corrugations **202** are constructed to enlarge the bandwidth of the antenna.

In the characteristic embodiment shown in FIG. **2**, the ridges **207** of the corrugations **202** are directed perpendicularly to the longer side of the second conductive patch **203**. In this case, the electrical field radiated from the second conductive patch **203** is perpendicular to the ridges **207** of the corrugations **202**. As a result, the electromagnetic properties of the corrugations **202** can be approximately described by a one-dimensional capacitive grid, for which the impedance, Z(g,cap), can be roughly written as:

$$Z(g,\mathrm{cap})=-Zs\cdot j/(4\cdot(t/\lambda)\cdot\ln(\mathrm{cosec}(\pi\cdot w/2t))) \tag{2}$$

Therefore, corrugations of a patch in which ridges are oriented perpendicularly to the wider side of the feeding second patch give another impedance-transforming circuit.

(Related Art)

In FIG. **3**, a construction of a relating art patch antenna is shown. In this construction, a first conductive patch **301** without corrugations and a second conductive patch **303** are formed in a multilayer substrate **304**. The second conductive patch **303** is connected to a feeding point **308**.

## Third Embodiment

Another exemplary embodiment of the broadband patch antenna is presented in FIGS. **4**A to **4**D. FIG. **4**A is a top view of this antenna. FIG. **4**B is a vertical cross-sectional view of this antenna on the **4**B section in FIG. **4**A. FIG. **4**C is a vertical cross-sectional view of this antenna on the **4**C section in FIG. **4**A. FIG. **4**D is a horizontal cross-sectional view of this antenna on the **4**D section in FIGS. **4**B and **4**C.

In this embodiment, the antenna shown in these figures is formed in a 3-conductor-layer substrate **404**. The 3-conductor-layer substrate **404** includes a first conductive layer **4**L**1**, a second conductive layer **4**L**2**, a third conductive layer **4**L**3** and an isolating material **406**.

The first conductive layer **4**L**1** includes a first conductive patch **401**. The second conductive layer **4**L**2** includes a second conductive patch **403**. The third conductive layer **4**L**3** includes a ground plane **405**. The first conductive patch **401** has a square shape with corrugations **402** on two opposing sides. The corrugations **402** include rectangular ridges **407** and rectangular grooves **409**. The second conductive patch **403** has a rectangular shape.

The second conductive layer **4**L**2** is disposed below the first conductive layer **4**L**1**. The third conductive layer **4**L**3** is disposed below the second conductive layer **4**L**2**. Consequently, the second conductive patch **403** is disposed below the first conductive patch **401**, and the ground plane **405** is disposed below the second conductive patch **403**. One end of the second conductive patch **403** is connected to a feeding point **408**. The isolating material **406** is disposed between the first conductive patch **401** and the second conductive patch **403**, and between the second patch **403** and the ground plane **405**.

In this antenna, ridges **407** of the corrugations **402** are directed in parallel to the longer side of the second conductive patch **403**. In such way, an enlargement of the bandwidth is provided.

### Fourth Embodiment

In FIGS. **5**A to **5**D, another exemplary embodiment of the broadband patch antenna is given. FIG. **5**A is a top view of this antenna. FIG. **5**B is a vertical cross-sectional view of this antenna on the **5**B section in FIG. **5**A. FIG. **5**C is a vertical cross-sectional view of this antenna on the **5**C section in FIG. **5**A. FIG. **5**D is a horizontal cross-sectional view of this antenna on the **5**D section in FIGS. **5**B and **5**C.

In this embodiment, the antenna shown in these figure is formed in a 3-conductor-layer substrate **504**. The 3-conductor-layer substrate **504** includes a first conductive layer **5L1**, a second conductive layer **5L2**, a third conductive layer **5L3** and an isolating material **506**.

The first conductive layer **5L1** includes a first conductive patch **501**. The second conductive layer **5L2** includes a second conductive patch **503**. The third conductive layer **5L3** includes a ground plane **505**. The first conductive patch **501** has a square shape with corrugations **502** on two opposing sides. The corrugations **502** include rectangular ridges **507** and rectangular grooves **509**. The second conductive patch **503** has a rectangular shape.

The second conductive layer **5L2** is disposed below the first conductive layer **5L1**. The third conductive layer **5L3** is disposed below the second conductive layer **5L2**. Consequently, the second conductive patch **503** is disposed below the first conductive patch **501**, and the ground plane **505** is disposed below the second conductive patch **503**. One end of the second conductive patch **503** is connected to a feeding point **508**. The isolating material **506** is disposed between the first conductive patch **501** and the second conductive patch **503**, and between the second patch **503** and the ground plane **505**.

In this antenna, ridges **507** of the corrugations **502** are directed perpendicularly to the longer side of the second conductive patch **503**.

To show an effect of corrugations on the bandwidth, the return loss (|S11|-parameter) was simulated for an invented patch antenna and a relating art patch antenna by the Finite-Difference Time-Domain (FDTD) technique, which is one of the most widely-used methods.

The invented patch antenna considered is similar to that shown in FIGS. **4**A-**4**D. Characteristics parameters of this antenna are as following: the side S of the first conductive patch **401** having a square form is 0.75 mm; the width Wp of the second conductive patch **403** is 0.08 mm; the total thickness TTh of the substrate **404** is 0.53 mm; and the thickness Th of the first, second and third conductive layers **4L1**, **4L2** and **4L3** is 0.01 mm each. As isolating material **406**, the LTCC (Low Temperature Co-firing Ceramic) with relative permittivity of 5.3 and loss tangent of 0.004 is used. In the simulated antenna, the corrugations have such dimensions: the width w of the ridges **407** is 0.05 mm; the pitch t of the corrugations **402** is 0.1 mm; and the depth D of the grooves **409** is 0.18 mm.

In FIG. **6**, a group of two graphs is shown. The first graph **601** shows a numerical result of the case when the patch antenna is obtained with smooth sided patch without application of corrugations, similar to the related art patch antenna shown in FIG. **3**. The second graph **602** shows a simulated data for the above mentioned antenna with corrugated patch similar to FIGS. **4**A to **4**D.

As one can see, the antenna with corrugated patch has considerably wider bandwidth compared with the antenna with smooth sided patch.

It should be noted that the corrugation depth D is an effective parameter to control the bandwidth of the patch antenna of the present invention. In FIG. **7**, a group of two graphs is shown. The first graph **701** is identical to the first graph **601** in FIG. **6**. The second graph **702** shows a simulated data for the patch antenna with corrugations having the depth D of 0.22 mm. In this antenna, other dimensions are the same as in FIG. **6**. Thus, an increase of the corrugation depth, as follows from this figure, can lead to widening the bandwidth of the patch antenna.



### Fifth Embodiment

Invented broad patch antennas can be used as elements to form an antenna array. In FIG. **8**, an exemplary embodiment of an antenna array of the present invention is shown. This antenna array is an arrangement of two antenna elements formed in a multilayer substrate **804**.

A first antenna element of the antenna array shown in FIG. **8** is similar to the antenna shown in FIGS. **4**A to **4**D. The first antenna element includes: a first conductive patch **801** and a second conductive patch **803**. The first conductive patch **801** has a rectangular shape with corrugations **802** on two opposing sides. The corrugations **802** include rectangular ridges **807** and rectangular grooves **809**. One end of the second conductive patch **803** is connected to a feeding point **808**. Other properties, dispositions and relationship of the first conductive patch **801**, the second conductive patch **803**, the corrugations **802**, the ridges **807**, the grooves **809** and the feeding point **808** shown in FIG. **8** are similar to those of the first conductive patch **401**, the second conductive patch **403**, the corrugations **402**, the ridges **407**, the grooves **409** and the feeding point **408** shown in FIG. **4**, respectively.

A second antenna element of the antenna array shown in FIG. **8** is similar to the antenna shown in FIGS. **5**A to **5**D. The second antenna element includes: a first conductive patch **811** and a second conductive patch **813**. The first conductive patch **811** has a rectangular shape with corrugations **812** on two opposing sides. The corrugations **812** include rectangular ridges **817** and rectangular grooves **819**. One end of the second conductive patch **813** is connected to a feeding point **818**. Other properties, dispositions and relationship of the first conductive patch **811**, the second conductive patch **813**, the corrugations **812**, the ridges **817**, the grooves **819** and the feeding point **818** shown in FIG. **8** are similar to those of the first conductive patch **501**, the second conductive patch **503**, the corrugations **502**, the ridges **507**, the grooves **509** and the feeding point **508** shown in FIG. **5**, respectively.

The second conductive patches **803** and **813** are disposed in parallel. In the first element, ridges of corrugations **802** are directed in parallel to the longer side of the second conductive patch **803**, while in the second element, the ridges of corrugations **812** are orientated perpendicularly to the longer side of the second conductive patch **813**. It should be emphasized that the antenna array presented in FIG. **8** is especially useful to obtain circular or elliptical polarization of the radiated field.

### Sixth Embodiment

Another exemplary embodiment of the antenna array is presented in FIG. **9**. This antenna array is an arrangement of two antenna elements formed in a multilayer substrate **904**.

Both a first antenna element and a second antenna element of the antenna array shown in FIG. **9** are similar to the antenna shown in FIGS. **4**A to **4**D. The first antenna element includes: a first conductive patch **901** and a second conductive patch **903**. The first conductive patch **901** has a rectangular shape with corrugations **902** on two opposing sides. The corrugations **902** include rectangular ridges **907** and rectangular grooves **909**. One end of the second conductive patch **903** is connected to a feeding point **908**. Other properties, dispositions and relationship of the first conductive patch **901**, the second conductive patch **903**, the corrugations **902**, the ridges **907**, the grooves **909** and the feeding point **908** shown in FIG. **9** are similar to those of the first conductive patch **401**, the second conductive patch **403**, the corrugations **402**, the ridges **407**, the grooves **409** and the feeding point **408** shown in FIG. **4**, respectively.

The second antenna element includes: a first conductive patch **911** and a second conductive patch **913**. The first conductive patch **911** has a rectangular shape with corrugations **912** on two opposing sides. The corrugations **912** include rectangular ridges **917** and rectangular grooves **919**. One end of the second conductive patch **913** is connected to a feeding point **918**. Other properties, dispositions and relationship of the first conductive patch **911**, the second conductive patch **913**, the corrugations **912**, the ridges **917**, the grooves **919** and the feeding point **918** shown in FIG. **9** are similar to those of the first conductive patch **401**, the second conductive patch **403**, the corrugations **402**, the ridges **407**, the grooves **409** and the feeding point **408** shown in FIG. **4**, respectively.

The second conductive patches **903** and **913** are disposed in parallel. In the first and second antenna elements, ridges **907** and **917** of corrugations **902** and **912** are oriented in parallel to the longer side of the second conductive patches **903** and **913**.

## Seventh Embodiment

It should be well understandable that a number of antenna elements forming an antenna array can be different. In FIG. **10**, an exemplary embodiment of an antenna array with four antenna elements is shown. Those four antenna elements are formed in a multilayer substrate **1004**.

Each of the four antenna element of the antenna array shown in FIG. **10** is similar to the antenna shown in FIGS. **4**A to **4**D. The first antenna element includes: a first conductive patch **1001** and a second conductive patch **1003**. The first conductive patch **1001** has a rectangular shape with corrugations **1002** on two opposing sides. The corrugations **1002** include rectangular ridges **1007** and rectangular grooves **1009**. One end of the second conductive patch **1003** is connected to a feeding point **1008**. Other properties, dispositions and relationship of the first conductive patch **1001**, the second conductive patch **1003**, the corrugations **1002**, the ridges **1007**, the grooves **1009** and the feeding point **1008** shown in FIG. **10** are similar to those of the first conductive patch **401**, the second conductive patch **403**, the corrugations **402**, the ridges **407**, the grooves **409** and the feeding point **408** shown in FIG. **4**, respectively.

The second antenna element includes: a first conductive patch **1011** and a second conductive patch **1013**. The first conductive patch **1011** has a rectangular shape with corrugations **1012** on two opposing sides. The corrugations **1012** include rectangular ridges **1017** and rectangular grooves **1019**. One end of the second conductive patch **1013** is connected to a feeding point **1018**. Other properties, dispositions and relationship of the first conductive patch **1011**, the second conductive patch **1013**, the corrugations **1012**, the ridges **1017**, the grooves **1019** and the feeding point **1018** shown in FIG. **10** are similar to those of the first conductive patch **401**, the second conductive patch **403**, the corrugations **402**, the ridges **407**, the grooves **409** and the feeding point **408** shown in FIG. **4**, respectively.

The third antenna element includes: a first conductive patch **1021** and a second conductive patch **1023**. The first conductive patch **1021** has a rectangular shape with corrugations **1022** on two opposing sides. The corrugations **1022** include rectangular ridges **1027** and rectangular grooves **1029**. One end of the second conductive patch **1023** is connected to a feeding point **1028**. Other properties, dispositions and relationship of the first conductive patch **1021**, the second conductive patch **1023**, the corrugations **1022**, the ridges **1027**, the grooves **1029** and the feeding point **1028** shown in FIG. **10** are similar to those of the first conductive patch **401**, the second conductive patch **403**, the corrugations **402**, the ridges **407**, the grooves **409** and the feeding point **408** shown in FIG. **4**, respectively.

The fourth antenna element includes: a first conductive patch **1031** and a second conductive patch **1033**. The first conductive patch **1031** has a rectangular shape with corrugations **1032** on two opposing sides. The corrugations **1032** include rectangular ridges **1037** and rectangular grooves **1039**. One end of the second conductive patch **1033** is connected to a feeding point **1038**. Other properties, dispositions and relationship of the first conductive patch **1031**, the second conductive patch **1033**, the corrugations **1032**, the ridges **1037**, the grooves **1039** and the feeding point **1038** shown in FIG. **10** are similar to those of the first conductive patch **401**, the second conductive patch **403**, the corrugations **402**, the ridges **407**, the grooves **409** and the feeding point **408** shown in FIG. **4**, respectively.

The second conductive patches **1003**, **1013**, **1023** and **1033** are disposed in parallel. The second conductive patches **1003** and **1033** are aligned in opposite direction. The second conductive patches **1013** and **1023** are aligned in opposite direction. The first conductive patches **1001**, **1011**, **1021** and **1031** are disposed in such way that their centers are arranged on each corner of a rectangle or a square. Ridges **1007**, **1017**, **1027** and **1037** of the corrugations **1002**, **1012**, **1022** and **1032** in these antenna elements are oriented in parallel to the longer side of the second conductive patches **1003**, **1013**, **1023** and **1033**, respectively.

## Eighth Embodiment

Another exemplary embodiment of the antenna array with four antenna elements is shown in FIG. **11**. In this embodiment, those four elements are disposed in a multilayer substrate **1104**.

A first antenna element of the antenna array shown in FIG. **11** is similar to the antenna shown in FIGS. **4**A to **4**D. The first antenna element includes: a first conductive patch **1101** and a second conductive patch **1103**. The first conductive patch **1101** has a rectangular shape with corrugations **1102** on two opposing sides. The corrugations **1102** include rectangular ridges **1107** and rectangular grooves **1109**. One end of the second conductive patch **1103** is connected to a feeding point **1108**. Other properties, dispositions and relationship of the first conductive patch **1101**, the second conductive patch **1103**, the corrugations **1102**, the ridges **1107**, the grooves **1109** and the feeding point **1108** shown in FIG. **11** are similar to those of the first conductive patch **401**, the second conductive patch **403**, the corrugations **402**, the ridges **407**, the grooves **409** and the feeding point **408** shown in FIG. **4**, respectively.

A second antenna element of the antenna array shown in FIG. **11** is similar to the antenna shown in FIGS. **5**A to **5**D. The second antenna element includes: a first conductive patch **1111** and a second conductive patch **1113**. The first conductive patch **1111** has a rectangular shape with corrugations **1112** on two opposing sides. The corrugations **1112** include rectangular ridges **1117** and rectangular grooves **1119**. One end of the second conductive patch **1113** is connected to a feeding point **1118**. Other properties, dispositions and relationship of the first conductive patch **1111**, the second conductive patch **1113**, the corrugations **1112**, the ridges **1117**, the grooves **1119** and the feeding point **1118** shown in FIG. **11** are similar to those of the first conductive patch **501**, the second conductive patch **503**, the corrugations **502**, the ridges **507**, the grooves **509** and the feeding point **508** shown in FIG. **5**, respectively.

A third antenna element of the antenna array shown in FIG. **11** is similar to the antenna shown in FIGS. **4**A to **4**D. The third antenna element includes: a first conductive patch **1121** and a second conductive patch **1123**. The first conductive patch **1121** has a rectangular shape with corrugations **1122** on two opposing sides. The corrugations **1122** include rectangular ridges **1127** and rectangular grooves **1129**. One end of the second conductive patch **1123** is connected to a feeding point **1128**. Other properties, dispositions and relationship of the first conductive patch **1121**, the second conductive patch **1123**, the corrugations **1122**, the ridges **1127**, the grooves **1129** and the feeding point **1128** shown in FIG. **11** are similar to those of the first conductive patch **401**, the second conductive patch **403**, the corrugations **402**, the ridges **407**, the grooves **409** and the feeding point **408** shown in FIG. **4**, respectively.

A fourth antenna element of the antenna array shown in FIG. **11** is similar to the antenna shown in FIGS. **5**A to **5**D. The fourth antenna element includes: a first conductive patch **1131** and a second conductive patch **1133**. The first conductive patch **1131** has a rectangular shape with corrugations **1132** on two opposing sides. The corrugations **1132** include rectangular ridges **1137** and rectangular grooves **1139**. One end of the second conductive patch **1133** is connected to a feeding point **1138**. Other properties, dispositions and relationship of the first conductive patch **1131**, the second conductive patch **1133**, the corrugations **1132**, the ridges **1137**, the grooves **1139** and the feeding point **1138** shown in FIG. **11** are similar to those of the first conductive patch **501**, the second conductive patch **503**, the corrugations **502**, the ridges **507**, the grooves **509** and the feeding point **508** shown in FIG. **5**, respectively.

The second conductive patches **1103**, **1113**, **1123** and **1133** are disposed in parallel. The second conductive patches **1103** and **1133** are aligned in opposite direction. The second conductive patches **1113** and **1123** are aligned in opposite direction. The first conductive patches **1101**, **1111**, **1121** and **1131** are disposed in such way that their centers are arranged on each corner of a rectangle or a square.

It should be noted that ridges **1107** and **1127** of the corrugations **1102** and **1122** are directed in parallel to the longer side of the second rectangular conductive patches **1103** and **1123**, respectively, while ridges **1117** and **1137** of the corrugations **1112** and **1132** are oriented perpendicularly to the longer side of the second rectangular conductive patches **1113** and **1133**, respectively. Such arrangement of antenna elements can be applied to obtain circular or elliptical polarization of radiation field.

## Ninth Embodiment

In FIG. **12**, another exemplary embodiment of the antenna array with four antenna elements is presented. In this embodiment, those four antenna elements are disposed in a multilayer substrate **1204**.

A first antenna element of the antenna array shown in FIG. **12** is similar to the antenna shown in FIGS. **4**A to **4**D. The first antenna element includes: a first conductive patch **1201** and a second conductive patch **1203**. The first conductive patch **1201** has a rectangular shape with corrugations **1202** on two opposing sides. The corrugations **1202** include rectangular ridges **1207** and rectangular grooves **1209**. One end of the second conductive patch **1203** is connected to a feeding point **1208**. Other properties, dispositions and relationship of the first conductive patch **1201**, the second conductive patch **1203**, the corrugations **1202**, the ridges **1207**, the grooves **1209** and the feeding point **1208** shown in FIG. **12** are similar to those of the first conductive patch **401**, the second conductive patch **403**, the corrugations **402**, the ridges **407**, the grooves **409** and the feeding point **408** shown in FIG. **4**, respectively.

A second antenna element of the antenna array shown in FIG. **12** is similar to the antenna shown in FIGS. **5**A to **5**D. The second antenna element includes: a first conductive patch **1211** and a second conductive patch **1213**. The first conductive patch **1211** has a rectangular shape with corrugations **1212** on two opposing sides. The corrugations **1212** include rectangular ridges **1217** and rectangular grooves **1219**. One end of the second conductive patch **1213** is connected to a feeding point **1218**. Other properties, dispositions and relationship of the first conductive patch **1211**, the second conductive patch **1213**, the corrugations **1212**, the ridges **1217**, the grooves **1219** and the feeding point **1218** shown in FIG. **12** are similar to those of the first conductive patch **501**, the second conductive patch **503**, the corrugations **502**, the ridges **507**, the grooves **509** and the feeding point **508** shown in FIG. **5**, respectively.

A third antenna element of the antenna array shown in FIG. **12** is similar to the antenna shown in FIGS. **5**A to **5**D. The third antenna element includes: a first conductive patch **1221** and a second conductive patch **1223**. The first conductive patch **1221** has a rectangular shape with corrugations **1222** on two opposing sides. The corrugations **1222** include rectangular ridges **1227** and rectangular grooves **1229**. One end of the second conductive patch **1223** is connected to a feeding point **1228**. Other properties, dispositions and relationship of the first conductive patch **1221**, the second conductive patch **1223**, the corrugations **1222**, the ridges **1227**, the grooves **1229** and the feeding point **1228** shown in FIG. **12** are similar to those of the first conductive patch **501**, the second conductive patch **503**, the corrugations **502**, the ridges **507**, the grooves **509** and the feeding point **508** shown in FIG. **5**, respectively.

A fourth antenna element of the antenna array shown in FIG. **12** is similar to the antenna shown in FIGS. **4**A to **4**D. The fourth antenna element includes: a first conductive patch **1231** and a second conductive patch **1233**. The first conductive patch **1231** has a rectangular shape with corrugations **1232** on two opposing sides. The corrugations **1232** include rectangular ridges **1237** and rectangular grooves **1239**. One end of the second conductive patch **1233** is connected to a feeding point **1238**. Other properties, dispositions and relationship of the first conductive patch **1231**, the second conductive patch **1233**, the corrugations **1232**, the ridges **1237**, the grooves **1239** and the feeding point **1238** shown in FIG. **12** are similar to those of the first conductive patch **401**, the second conductive patch **403**, the corrugations **402**, the ridges **407**, the grooves **409** and the feeding point **408** shown in FIG. **4**, respectively.

The second conductive patches **1203**, **1213**, **1223** and **1233** are disposed in parallel. The second conductive patches **1203** and **1233** are aligned in opposite direction. The second conductive patches **1213** and **1223** are aligned in opposite direction. The first conductive patches **1201**, **1211**, **1221** and **1231** are disposed in such way that their centers are arranged on each corner of a rectangle or a square.

In this exemplary embodiment, ridges **1207** and **1237** of the corrugations **1202** and **1232** are directed in parallel to the longer side of the second rectangular conductive patches **1203** and **1233**, respectively, while ridges **1217** and **1227** of the corrugations **1212** and **1222** are oriented perpendicularly to the longer side of the second rectangular conductive patches **1213** and **1223**, respectively. This distribution of antenna elements can be also used to obtain circular or elliptical polarization of radiation field.

While the present invention has been described in relation to some exemplary embodiments, it is to be understood that these exemplary embodiments are for the purpose of description by example, and not of limitation. While it will be obvious to those skilled in the art upon reading the present specification that various changes and substitutions may be easily made by similar components and art, it is obvious that such changes and substitutions lie within the true scope and spirit of the presented invention as defined by the claims.

What is claimed is:

**1**. An antenna comprising:

a ground plane;

a first conductive patch disposed in parallel to said ground plane and having a rectangular shape with corrugations on two opposing sides; and

a second conductive patch disposed in parallel to both said ground plane and said first conductive path, disposed between said ground plane and said first conductive patch, and connected to a feeding point;

wherein said second conductive patch overcrosses said first conductive patch, and

wherein said corrugations of said first conductive patch and said second conductive patch form a configuration providing a one-dimensional grid effect due to a predetermined orientation of the said corrugations in said first conductive patch and said second conductive patch, together with said overcrossing of said first conductive patch by said second conductive patch; and

wherein said one-dimensional grid effect provides an extension of the operation band of said antenna.

**2**. The antenna according to claim **1**,

wherein said corrugations comprise:

rectangular ridges; and

rectangular grooves.

**3**. The antenna according to claim **2**,

wherein said second conductive patch has a rectangular shape.

**4**. The antenna according to claim **3**,

wherein a longer side of said second conductive patch is in parallel to an orientation of said ridges providing said one-dimensional grid effect as an inductive one.

**5**. The antenna according to claim **3**,

wherein a longer side of said second conductive patch is perpendicular to an orientation of said ridges providing said one-dimensional grid effect as a capacitive one.

**6**. The antenna according to claim **3**, further comprising:

a third conductive patch included in a first conductor layer in which said first conductive patch is included;

a fourth conductive patch included in a second conductor layer in which said second conductive patch is included; and

an isolating material configured to isolate said first, said second, said third and said fourth conductive patches,

wherein said first conductive patch has a square shape with said corrugations on said two opposing side,

wherein said third conductive patch has a rectangular shape with corrugations on two opposing sides,

wherein said corrugations comprise:

rectangular ridges; and

rectangular grooves, and

wherein said fourth conductive patch has a rectangular shape with a longer side disposed in parallel to a longer side of said second conductive patch and is connected to a feeding point.

**7**. The antenna according to claim **6**,

wherein said longer side of said second conductive patch is in parallel to an orientation of said ridges of said first conductive patch, and

wherein said longer side of said fourth conductive patch is in parallel to an orientation of said ridges of said third conductive patch.

**8**. The antenna according to claim **6**,

wherein said longer side of said second conductive patch is in parallel to an orientation of said ridges of said first conductive patch, and

wherein said longer side of said fourth conductive patch is perpendicular to an orientation of said ridges of said third conductive patch.

**9**. The antenna according to claim **7**, further comprising:

a fifth conductive patch included in said first conductive layer;

a sixth conductive patch included in said second conductive layer;

a seventh conductive patch included in said first conductive layer; and

an eighth conductive patch included in said second conductive layer,

wherein said first, said second, said third, said fourth, said fifth, said sixth, said seventh and said eighth conductive patches are isolated from each other by said isolating material,

wherein each of said fifth and said seventh conductive patches has a rectangular shape with corrugations on two opposing sides,

wherein said corrugations comprise:

rectangular ridges; and

rectangular grooves,

wherein each of said sixth and said eighth conductive patches has a rectangular shape with a longer side disposed in parallel to said longer side of said second conductive patch and is connected to further a feeding point, and

wherein said ridges of said fifth and said seventh conductive patches are disposed in parallel to said longer side of said sixth and said eighth conductive patch, respectively.

**10**. The antenna according to claim **8**, further comprising:

a fifth conductive patch included in said first conductive layer;

a sixth conductive patch included in said second conductive layer;

a seventh conductive patch included in said first conductive layer; and

an eighth conductive patch included in said second conductive layer,

wherein said first, said second, said third, said fourth, said fifth, said sixth, said seventh and said eighth conductive patches are isolated from each other by said isolating material, wherein each of said fifth and said seventh conductive patches has a rectangular shape with corrugations on two opposing sides,

wherein said corrugations comprise:

rectangular ridges; and

rectangular grooves,

wherein each of said sixth and said eighth conductive patches has a rectangular shape with a longer side disposed in parallel to said longer side of said second conductive patch and is connected to further a feeding point,

wherein said ridges of said fifth conductive patch are disposed in parallel to said longer side of said sixth conductive patch, and

wherein said ridges of said seventh conductive patches are disposed perpendicularly to said longer side of said eighth conductive patch.

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